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Finite element modelling of the growth and flow properties of multiple-scale three-dimensional fracture networks

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The generation and growth of multiple three-dimensional fractures, and fluid flow through the resultant fractured rock mass, is modelled by solving the displacement and flow equations numerically, using the finite element method. The approach uses the Imperial College Geomechanics Toolkit, an in-house C++ 3D simulator that captures coupled thermo-poro-elastic deformation and damage accumulation, while accounting for variable fracture apertures and local transmissivities on the fracture surface, which evolve as a function of deformation. Simulations are able to capture fracture growth at different scales, and model fracture nucleation based on the evaluation of a local damage model. Quasi-static fracture growth is simulated for a number of different stress regimes, making use of a new geometric representation of fractures, based on a novel periodic quadratic polynomial spatial B-spline approach. Surfaces are formed by lofting tip curves during fracture growth, resulting in a low-cost, high-resolution approach. Meshing of the domain uses quadratic quadrilaterals and hexahedra, as opposed to triangles and tetrahedra. The generated fractures are generally non-planar, due to the varying crack-tip stress intensity factors created by stress field interactions between neighboring fractures. Realistic three-dimensional fracture patterns emerge from the simulations, due to nucleation, growth, interaction and intersection of fractures at several scales. Datasets with thousands of geomechanically interacting discrete fractures at different scales will be presented. Fluid flow through the generated fractured rock mass exhibits interesting channeling effects, which are strongly influenced by the stress regime.

Participation

In-Person

References

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